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Applicant: **WESTINGHOUSE ELECTRIC CORPORATION**, Westinghouse Building Gateway Center, Pittsburgh Pennsylvania 15235 (US)

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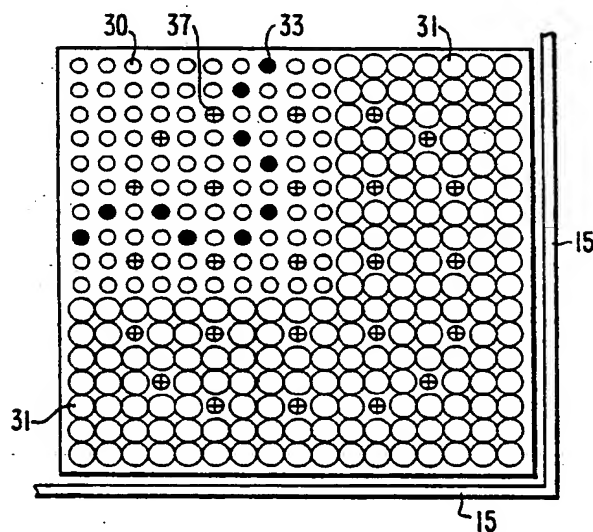
Inventor: **Camden, Thomas Martin, Jr.**, RD 1, Raintree Drive, Apollo Pennsylvania (US)  
Inventor: **Orr, William Lawrence**, 105 Tall Timber Drive, Ligonier Pennsylvania (US)

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Representative: **van Berlyn, Ronald Gilbert**, 23, Centre Heights, London, NW3 6JG (GB)

Maximum power capability blanket for nuclear reactors.

A blanket assembly for a nuclear reactor core perimeter region having at least two regions within the assembly of different H/U ratios, rod enrichments and rod diameters.



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MAXIMUM POWER CAPABILITY BLANKET  
FOR NUCLEAR REACTORS

This invention relates to an improved radial blanket for the cores of nuclear reactors, particularly pressurized water reactors (PWR).

5 Nuclear reactors have a grouping of fuel assemblies in an array termed the core. The fuel assemblies each comprise an array of cylindrical rods containing fissile fuel. Energy is produced in the reactor by neutron-induced fission reactions in the fuel.

10 The array of fuel assemblies forms a structure which is approximately a right circular cylinder. The fuel assemblies located on the perimeter of the core may have characteristics which in the industry cause these assemblies to be termed "radial blanket" assemblies.

15 The application of radial blankets of fertile material to the periphery of PWR cores has been studied extensively. The principal goal of conventional blankets has been to capture neutrons that would otherwise have escaped the fuel core in fertile material, thereby producing fissile material. The impediment to this strategy  
20 which has prohibited the use of these blankets in PWR's to date is power peaking that results inboard in the core. This power peaking is the result of displacing peripheral fuel assemblies of enriched fuel with low reactivity, fertile material. The conclusion which has been reached  
25 repeatedly in the industry is that the resulting power

peaking is unacceptable. Other attempts to successfully install radial blankets in PWR's have employed radical fuel design or core structure changes, e.g., installing fertile material in the zone between a core baffle and barrel or reducing the fuel assembly size by a factor of four to permit installation of smaller fertile assemblies around the periphery. These alternatives are accompanied by departures from existing core designs which are not merited by the resulting neutron utilization improvement.

10 The application of radial blankets in boiling water reactors (BWR's) has been successful primarily due to the already reduced size of BWR fuel assemblies (about  $\frac{1}{2}$  of PWR size).

Consequently, it is the principal object of the present invention to provide a blanket assembly arrangement that can be used to capture neutrons at the core perimeter so as to reduce core leakage with an acceptable core power peaking factor.

With this object in view, the present invention resides in a blanket assembly for a nuclear reactor core peripheral region comprising an array of rods supported one adjacent another in a support frame, characterized in that said assembly has a first region of small rods of a first diameter substantially smaller than their center-to-center distance so as to provide a gap between adjacent rods adapted to be filled with water so as to provide for a predetermined hydrogen-to-uranium ratio in the first region, said small rods in said first region containing fuel of a first enrichment, and a second region of large rods of a second diameter, which is greater than said first diameter, said large rods containing fuel of a second enrichment of fuel, which is less than said first enrichment, and said second region having a hydrogen-to-uranium ratio which is less than that of the first region, said assembly being adapted to be disposed in said peripheral region such that said first region is directed toward the center of said core, and said second region is disposed adjacent the circumference of said core.

The invention will become more readily apparent from the following description of a preferred embodiment thereof shown, by way of example only, in the accompanying drawings, wherein:

5           Fig. 1 is a schematic of a PWR;  
          Fig. 2 is a schematic of a PWR prior art fuel assembly;

          Fig. 3 is a profile of a PWR core;  
          Fig. 4 is a profile schematic of a PWR prior art  
10 fuel assembly;

          Fig. 5 is a profile schematic of a first embodiment of the invented blanket assembly; and

          Fig. 6 is a profile schematic of a second embodiment of the invented blanket assembly.

15           Referring to Fig. 1, there is shown a reactor vessel 10 housing a nuclear reactor core 12. The core 12 includes a plurality of parallel and coextending bundled-rod fuel elements 14 supported vertically by a structure within the vessel 10. The vessel 10 is sealed at the top  
20 by a head 16 from which there is supported control element drive mechanism 18 which selectively position control elements 20 above and within some of the fuel elements 14. During operation a reactor coolant fluid, such as water, is typically pumped into the vessel through a plurality of  
25 inlet nozzles 22, passes downward through an annular region 24 between the vessel and a core barrel 23 and thermal shield 25, turns in the vessel lower plenum 26, passes upwardly through the core 12, and exits through a plurality of outlet nozzles 28. The heat energy which the  
30 core imparts to the coolant is transferred in heat transfer apparatus (not shown) typically for the ultimate purpose of electrical power generation.

          A typical fuel element 14 of the bundled-rod type is shown in greater detail in Fig. 2. It includes a  
35 plurality of parallel and coextending fuel rods 30, each of which includes nuclear fuel pellets 32 stacked within a sealed metallic cladding 34. The fuel rods 30 are primar-

ily supported by upper 36 and lower 38 nozzles and by grid structures 40 spaced along the element length. The element is shown receiving a control element 20 of the "spider" type, including a plurality of cylindrical control rods 21, although plates, bars, singular rods, and so forth, can be used with varying element configurations. The control element 20 is comprised of a material having a high neutron absorption cross section, such as boron carbide, tantalum, a combination of silver-indium and cadmium, or many others well known in the art. It is to be understood that while an open-lattice or grid-type fuel element is shown, the teachings herein are applicable to other fuel element structures; including those referred to as ducted elements used in many reactor types, such as liquid metal cooled fast breeder reactors.

Fig. 3 shows that the fuel elements 14 are disposed in core locations in a regularly patterned array. The letters A through O and numerals 1 through 15 are herein utilized to reference a given core position. Core 12 is surrounded by a core baffle plate 15 which serves to channel coolant flow.

Fig. 4 is a schematic of a prior art fuel assembly having a 17 by 17 array of fuel rods 30.

This invention is to provide a maximum power capability blanket (MPC) assembly for core perimeter locations. Inspection of Fig. 3 shows there to be assemblies which present one face to core baffle plate 15 (see for example locations A-8, B-6, F-2 in Fig. 3) and assemblies which present two faces to core baffle plate 15 (see for example locations A-7, B-5, E-2 in Fig. 3).

The MPC blanket design is to substantially reduce neutron leakage with a minimum power peaking penalty. This accomplishment is provided through improved neutron reflection into adjacent enriched fuel within a blanket assembly of current PWR size which has both fertile zones and enriched zones. The MPC blanket assembly is placed at the periphery and remains at the periphery

throughout life. To improve the utilization of the enriched fuel in this peripheral area, the enriched zone has a high H/U lattice, where this H/U symbol is defined as the ratio between the hydrogen to the uranium characteristic of the rod array.

The improved reflection is provided by low H/U fertile blanket zones. The reduction of water (H) in the fertile zone maximizes the flux of reflected neutrons in the adjacent enriched fuel. The fertile material also performs the role of a traditional blanket, i.e., capturing escaping neutrons with fertile captures and subsequently producing power within the fertile zone.

One likely reason that multiple zone enrichment concepts have not been employed as radial blankets in the past is that one inevitably traps enriched fuel in an area of low utilization. The MPC blanket improves fuel utilization through appropriate H/U zoning. This same utilization improvement also provides a general flattening of power throughout the core which tends to offset the usual radial power peaking associated with radial blankets.

Specific first and second embodiments appropriate to use with non-blanket fuel of the type shown in Fig. 4 are shown in Figs. 5 and 6. Fig. 5 shows the embodiment for location in "one-face-to-baffle" locations while Fig. 6 is the embodiment for "two-faces-to-baffle" locations.

In these designs there are only two enrichments and two fuel rod sizes. The smaller fuel rod 34 is the same fuel rod 30 used in the rest of the core, and the presence of these smaller fuel rods 30 defines the area of the "enriched zone", which has a high H/U ratio. A low H/U in the fertile zone is obtained through oversized fertile fuel rods 31, the presence of which define the fertile zone.

The H/U ratio in the enriched zone is accomplished by removing fuel rods 33 near the boundary of the fertile zone. The importance of the neutron reflection from the fertile zone can be deduced by comparing the

results of cores using this configuration with and without an H/U adjustment in the fertile zone. The oversized rods by themselves represent a drop in cell reactivity of about 10%  $\Delta\rho$  compared to the smaller fuel rod cell. The impact of such a change by itself would be to lower core reactivity about 0.5%  $\Delta\rho$  and shift power substantially toward the middle of the core. The reflective benefits of the low H/U zone not only overcome this significant disadvantage but raise core reactivity about 0.1%  $\Delta\rho$  and draw power away from the core center to the adjacent enriched fuel zone.

It should also be noted that the configurations in Figs. 5 and 6 have incorporated variable enrichment and H/U zoning without a major structural redesign of the reference design shown in Fig. 4. There has been no change to the non-blanket assemblies and no change to the structure or arrangement of core internals. A side benefit of the configuration shown here is a reduction in fluence to the core vessel of about 50% over current fuel designs, since neutron leakage is reduced by approximately this amount.

In Figs. 4, 5 and 6 circles 37 represent control rod guide thimble locations.

## CLAIMS:

1. A blanket assembly for a nuclear reactor core peripheral region comprising an array of rods supported one adjacent another in a support frame, characterized in that said assembly (14) has a first region of  
5 small rods (30) of a first diameter substantially smaller than their center-to-center distance so as to provide a gap between adjacent rods (30) adapted to be filled with water so as to provide for a predetermined hydrogen-to-uranium ratio in the first region, said small rods (30) in  
10 said first region containing fuel of a first enrichment, and a second region of large rods (31) of a second diameter, which is greater than said first diameter, said large rods (31) containing fuel of a second enrichment of fuel, which is less than said first enrichment, and said  
15 second region (31) having a hydrogen-to-uranium ratio which is less than that of the first region, said assembly being adapted to be disposed in said peripheral region such that said first region is directed toward the center of said core, and said second region is disposed adjacent  
20 the circumference of said core.

2. A blanket assembly as claimed in claim 1, wherein said assembly has a square cross-section, characterized in that said second region is disposed within said assembly along two adjacent sides thereof for arrangement  
25 of said assembly in core corner positions adjacent the core baffle plates.



3. A blanket assembly as claimed in claim 1 or 2, characterized in that a plurality of array positions in said first region are without small rods, that is, they are empty positions adapted to be filled with water so as to increase the hydrogen-to-uranium ratio in said first region.

4. A blanket assembly as claimed in claim 1, 2 or 3, characterized in that the fuel rods in said first region are identical to the fuel rods in other fuel assemblies of said core located in the interior of said core.

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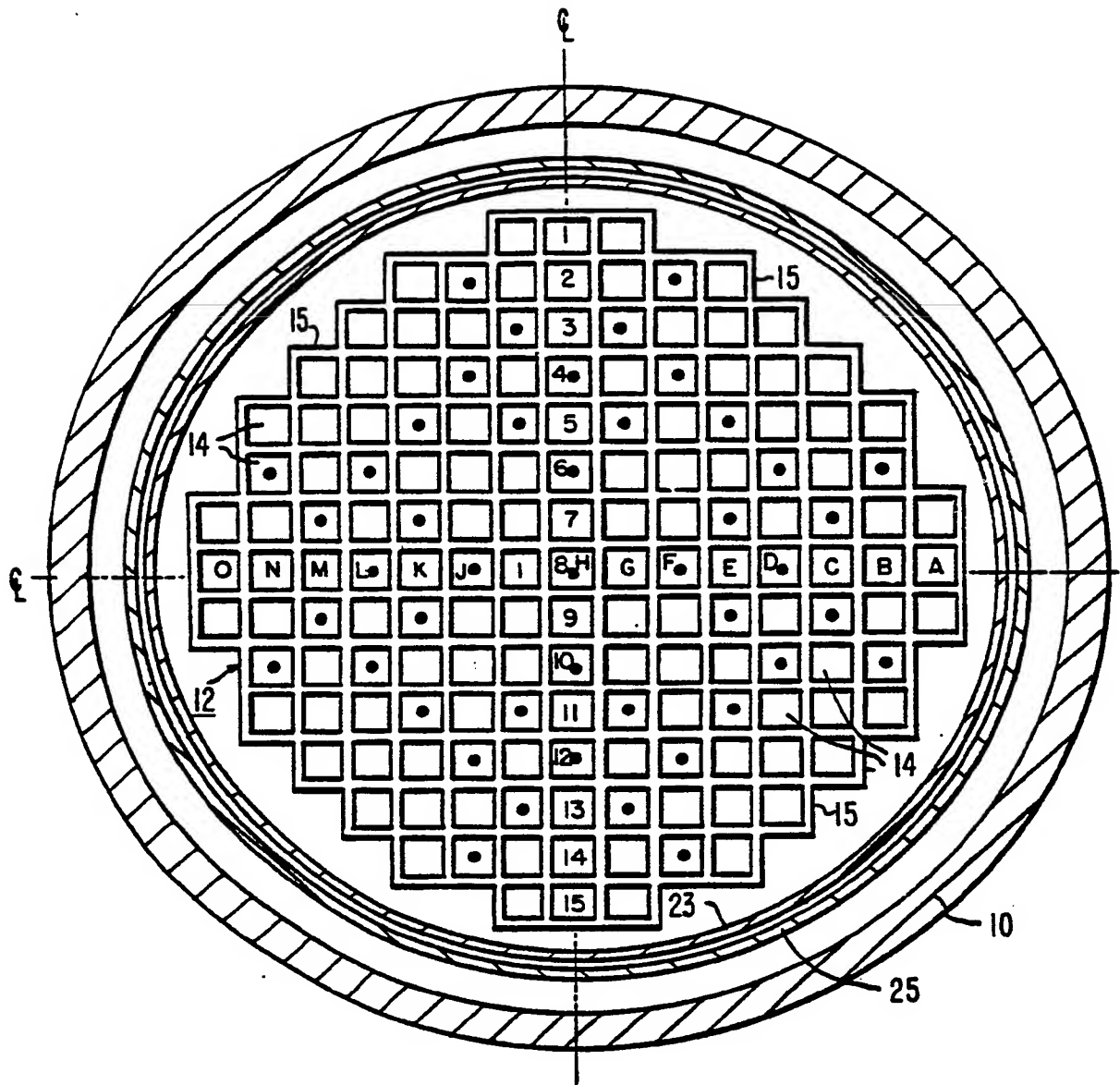


FIG. 3

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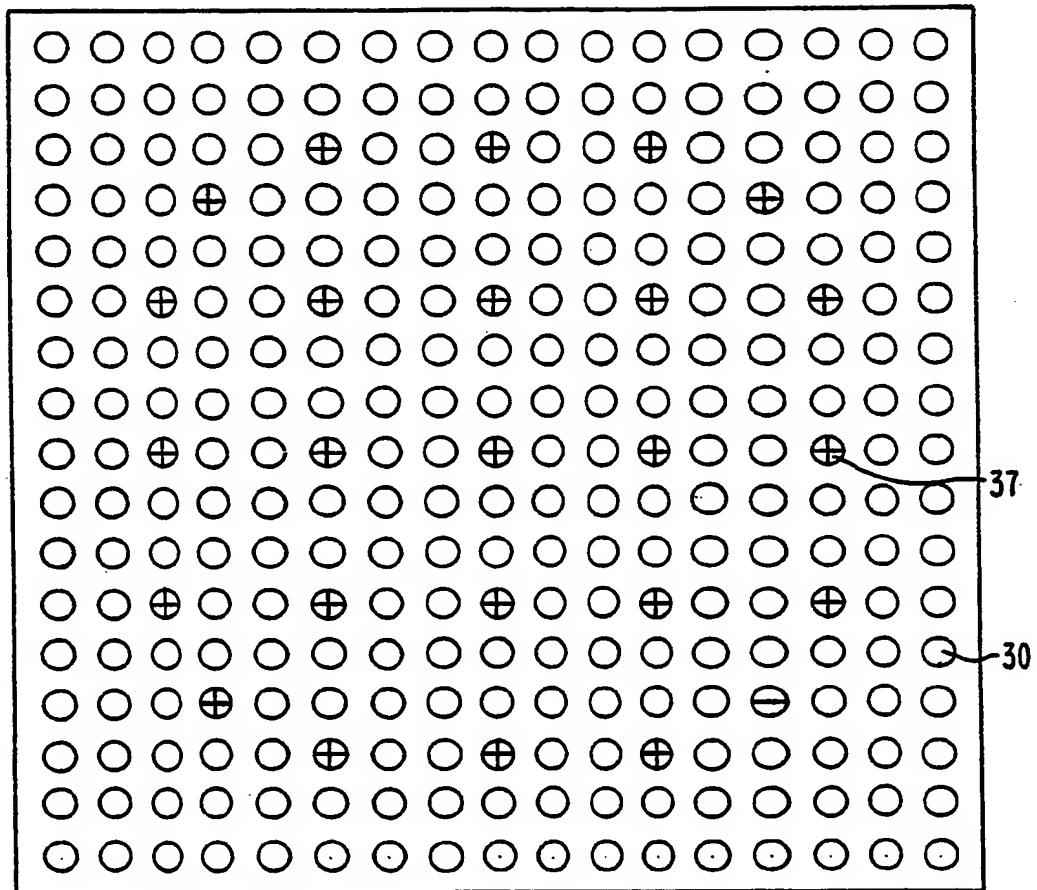


FIG. 4

PRIOR ART

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FIG. 5

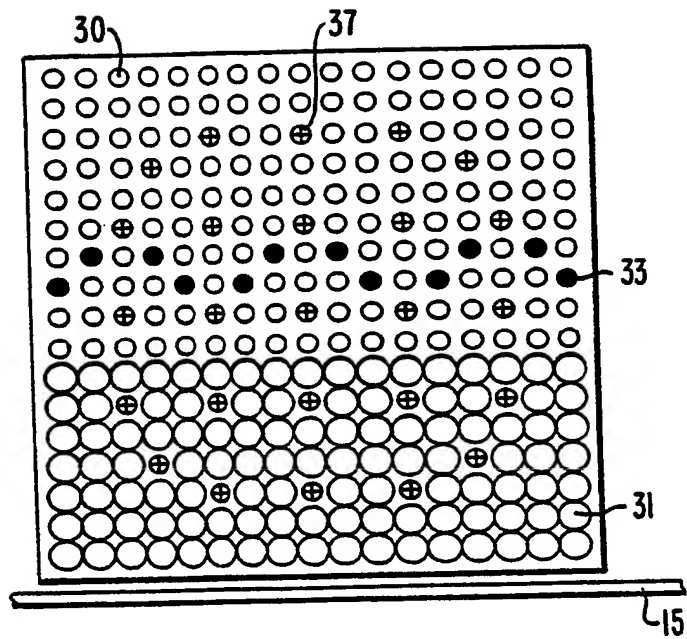
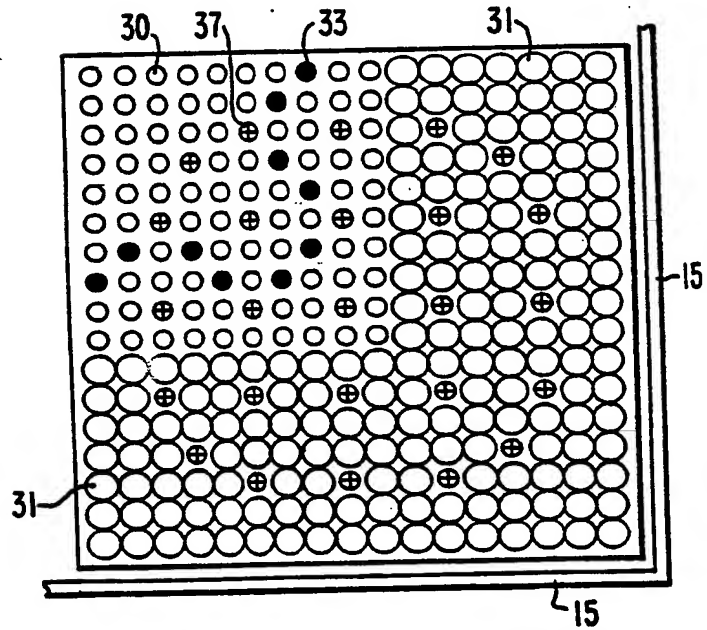


FIG. 6



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71 Applicant: **WESTINGHOUSE ELECTRIC CORPORATION**  
**Westinghouse Building Gateway Center**  
**Pittsburgh Pennsylvania 15235(US)**

72 Inventor: **Camden, Thomas Martin, Jr.**  
**RD 1, Raintree Drive**  
**Apollo Pennsylvania(US)**

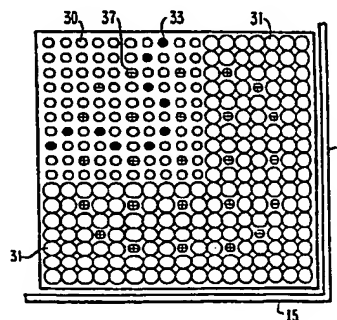
72 Inventor: **Orr, William Lawrence**  
**105 Tall Timber Drive**  
**Ligonier Pennsylvania(US)**

74 Representative: **van Berlyn, Ronald Gilbert**  
**23, Centre Heights**  
**London, NW3 6JG(GB)**

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FIG. 6





European Patent  
Office

# EUROPEAN SEARCH REPORT

0094255

Application number

EP 83 30 2661

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. <sup>3</sup> )
A	US-A-3 844 886 (R. CRAWTHER) * column 9, lines 36-65; figures 3,8-10 *	1,2	G 21 C 3/32
A	DE-B-1 187 332 (INTERATOM) * column 3, lines 58-64; figure 4 *	1,3	
A	FR-A-2 213 560 (WESTINGHOUSE) * page 7, lines 13-33; figure 4 *	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl. <sup>3</sup> )
			G 21 C 3/32 G 21 C 1/02 G 21 C 1/08 G 21 C 5/00
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 01-12-1983	Examiner GIANNI G.L.G.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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